

CLAIMS

1. A high-density electrode, comprising an electrode active substance and carbon fiber having a fiber filament diameter of 1 to 1,000 nm, wherein the porosity of the electrode is 25% or less.
5
2. The high-density electrode as claimed in claim 1, wherein the carbon fiber is graphite carbon fiber which has undergone thermal treatment at 2,000°C or higher.
10
3. The high-density electrode as claimed in claim 1, wherein the carbon fiber is graphite carbon fiber having a surface onto which an oxygen-containing functional group has been introduced through oxidation treatment.
15
4. The high-density electrode as claimed in claim 1, wherein the carbon fiber is graphite carbon fiber containing boron in an amount of 0.1 to 100,000 ppm.
20
5. The high-density electrode as claimed in claim 1, wherein the amount of the carbon fiber is 0.05 to 20 mass%.
6. The high-density electrode as claimed in claim 1, wherein the carbon fiber has an average aspect ratio of 5 to 50,000.
25
7. The high-density electrode as claimed in claim 2, wherein the graphite carbon fiber has, at a (002) plane, an average interlayer distance (d_{002}) of 0.344 nm or less as measured by means of X-ray diffractometry.
30
8. The high-density electrode as claimed in claim 1, wherein

the carbon fiber has, in its interior, a hollow structure.

9. The high-density electrode as claimed in claim 1, wherein the carbon fiber contains branched carbon fiber.

5

10. The high-density electrode as claimed in claim 1, wherein the electrode active substance is a carbon material.

11. The high-density electrode as claimed in claim 10, wherein the carbon material contains Si.

10

12. The high-density electrode as claimed in claim 10, wherein the carbon material is a non-graphite carbon material, and the bulk density of the electrode is 1.5 g/cm^3 or more.

15

13. The high-density electrode as claimed in claim 10, wherein, before being formed into an electrode, the carbon material serving as the electrode active substance is in the form of carbonaceous particles satisfying the following requirements:

20

(1) average roundness as measured by use of a flow particle image analyzer is 0.70 to 0.99; and

(2) average particle size as measured by means of laser diffractometry is 1 to $50 \text{ }\mu\text{m}$.

25

14. The high-density electrode as claimed in claim 10, wherein the carbon material contains a graphite material in an amount of 50 mass% or more, and the bulk density of the electrode is 1.7 g/cm^3 or more.

30

15. The high-density electrode as claimed in claim 14, wherein the graphite material contains boron.

16. The high-density electrode as claimed in claim 14, wherein, before being formed into an electrode, the carbon material serving as the electrode active substance is in the form of carbon particles containing, in an amount of 50 mass% or more, graphite particles satisfying the following requirements:

(1) average roundness as measured by use of a flow particle image analyzer is 0.70 to 0.99; and

(2) average particle size as measured by means of laser diffractometry is 1 to 50 μm .

17. The high-density electrode as claimed in claim 14, wherein the graphite material is carbon particles containing, in an amount of 50 mass% or more, graphite particles satisfying the following requirements:

(1) C_0 of a (002) plane as measured by means of X-ray diffractometry is 0.6900 nm, L_a (the size of a crystallite as measured along the a-axis) is greater than 100 nm, and L_c (the size of a crystallite as measured along the c-axis) is greater than 100 nm;

(2) BET specific surface area is 0.2 to 5 m^2/g ;

(3) true density is 2.20 g/cm^3 or more; and

(4) laser Raman R value (the ratio of the intensity of a peak at 1,360 cm^{-1} in a laser Raman spectrum to that of a peak at 1,580 cm^{-1} in the spectrum) is 0.01 to 0.9.

18. The high-density electrode as claimed in claim 1, wherein the electrode active substance is a Li alloy.

19. The high-density electrode as claimed in claim 1, wherein the electrode active substance is a lithium nitride material.

20. The high-density electrode as claimed in claim 1, wherein the electrode active substance is a silicon oxide material.

5 21. The high-density electrode as claimed in claim 1, wherein the electrode active substance is a metal oxide material.

22. The high-density electrode as claimed in claim 21, wherein the metal oxide material contains a tin oxide material
10 in an amount of 60 mass% or more.

23. The high-density electrode as claimed in claim 21, wherein the metal oxide material contains a cobalt oxide in an amount of 60 mass% or more, and the bulk density of the
15 electrode is 3.6 g/cm^3 or more.

24. The high-density electrode as claimed in claim 21, wherein the metal oxide material contains a manganese oxide in an amount of 60 mass% or more, and the bulk density of the
20 electrode is 3.0 g/cm^3 or more.

25. The high-density electrode as claimed in claim 21, wherein the metal oxide material contains a mixture of a cobalt oxide and a manganese oxide in an amount of 80 mass% or more,
25 and the bulk density of the electrode is 3.4 g/cm^3 or more.

26. The high-density electrode as claimed in claim 21, wherein the metal oxide material contains a nickel oxide in an amount of 60 mass% or more, and the bulk density of the
30 electrode is 3.4 g/cm^3 or more.

27. The high-density electrode as claimed in claim 21,

wherein the metal oxide material contains a vanadium oxide in an amount of 60 mass% or more, and the bulk density of the electrode is 2.3 g/cm³ or more.

5 28. The high-density electrode as claimed in claim 1, wherein the electrode active substance is a metal sulfide material.

29. The high-density electrode as claimed in claim 1, wherein the electrode active substance is an iron olivine compound.

10

30. The high-density electrode as claimed in claim 1, containing a carbon fiber having a filament diameter of 1 to 1,000 nm in an amount of 0.2 to 20 mass%, and having a capacity density of 100 mAh/g or higher and a high electrolytic solution permeability.

15

31. The high-density electrode as claimed in claim 30, wherein the electrode absorbs 3 μ l of propylene carbonate within 500 seconds at 25°C and 1 atm.

20

32. A battery comprising a high-density electrode as recited in any one of claims 1 through 31.

33. A secondary battery comprising a high-density electrode as recited in any one of claims 1 through 31.

25

34. The secondary battery as claimed in claim 33, which comprises a non-aqueous electrolytic solution and/or a non-aqueous polymer electrolyte, wherein a non-aqueous solvent employed for the non-aqueous electrolytic solution and/or the non-aqueous polymer electrolyte contains at least one species selected from the group consisting of ethylene carbonate,

30

diethyl carbonate, dimethyl carbonate, methyl ethyl carbonate, propylene carbonate, butylene carbonate, and vinylene carbonate.

35. A lithium battery electrode having high electrolytic
5 solution permeability, containing a carbon fiber having a filament diameter of 1 to 1,000 nm in an amount of 0.2 to 20 mass%, and the electrode having a capacity density of 100 mAh/g or higher.
- 10 36. The lithium battery electrode having high electrolytic solution permeability as claimed in claim 35, wherein the electrode absorbs 3 μ l of propylene carbonate within 500 seconds at 25°C and 1 atm.
- 15 37. A lithium secondary battery comprising the lithium battery electrode having high electrolytic solution permeability as recited in claim 35 or 36.